# INDOOR AIR QUALITY ASSESSMENT

**Lincoln Elementary School**
**161 Mystic Valley Parkway**
**Winchester, Massachusetts**


Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
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## Background/Introduction

At the request of a parent, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding potential indoor air quality concerns at the Lincoln Elementary School (LES), Winchester, MA. On May 6, 2003 a visit to conduct an assessment of the school was made by Cory Holmes and Sharon Lee, Environmental Analysts in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program. BEHA staff were accompanied by Rich Burchill, Principal, LES during the assessment. Mr. Holmes conducted a follow up visit on August 8, 2003 to take photographs of the building exterior and to examine repairs made to water damaged building materials. Water damaged materials are discussed further in the Microbial/Moisture Concerns section of this report.

The school is a three-story, brick structure built in 1903. An addition was built in 1950. BEHA staff previously visited the school in April of 1998 and issued a report documenting conditions noted at that time (MDPH, 1998). In 2001, the building underwent renovations, including an upgrade to the school's heating, ventilation and air conditioning (HVAC) systems.

The school contains general classrooms, science classrooms, a music room, computer labs, several resource rooms, an auditorium, a library-media center, gymnasium, a band room, several art rooms, computer rooms, a kitchen, cafeteria and office space. Windows throughout the building are openable.

## Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. Water content of gypsum wallboard (GW) was measured with a Delmhorst, BD-2000 Model, Moisture Detector with a Delmhorst Standard Probe.

## Results

The school houses students in grades K-5 with a student population of approximately 450 and a staff of approximately 40. Tests were taken during normal operations at the school and results appear in Table 1.

## Discussion

### Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million parts of air (ppm) in 16 of 19 areas surveyed, indicating adequate ventilation in most areas of the school. Fresh air in classrooms is supplied by a unit ventilator (univent) system (Picture 1). Classroom temperature and airflow from univents is controlled by a centralized computer system. Univents draw air from outdoors through fresh air intakes located on the exterior walls of the building (Picture 2) and return air through air intakes located at the base of each unit (Figure 1). Fresh air and return air are mixed, filtered, heated and distributed to classrooms through a fresh air diffuser located in the top of the unit. Some univents were found deactivated or obstructed (Table 1), preventing airflow.

In order for univents to provide fresh air as designed, they must be allowed to operate and remain free of obstructions.

The mechanical exhaust ventilation system in classrooms is provided by wall or ceiling-mounted exhaust vents (Picture 3). Exhaust air is expelled from the building by motorized exhaust vents located on the roof. These vents were operating throughout the building.

Mechanical ventilation in common areas such as the cafeteria, gymnasium and auditorium are provided by air handling units (AHUs). As with the univent system, AHUs are controlled from a central computer terminal. The activation of the cafeteria ventilation system appears to be dependent on a carbon dioxide sensor (Picture 4). Once a pre-set reading is exceeded, the AHU is activated to introduce fresh air. When a second, *lower* pre-set reading is measured by the sensor, the ventilation system is deactivated. Therefore, no mechanical ventilation is provided until the sensor re-activates the system. The cafeteria ventilation system was not operating during the lunch hour. In addition, the digital readout on the monitor read approximately 700 ppm as compared to the BEHA reading of 1,744 (over 1,000 ppm less than the BEHA measurement). School officials could not identify the date of calibration for this carbon dioxide monitor/HVAC controller.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order for univent and exhaust systems to provide proper ventilation, the systems must be balanced to supply an adequate amount of fresh air to the interior of a room while removing stale air from the room. The initial equipment balancing should have occurred after the installation of the new HVAC systems. It is recommended that HVAC systems be re-balanced every five years (SMACNA, 1994).

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows (BOCA, 1993; SBBRS, 1997). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information about carbon dioxide see Appendix I.

Temperature measurements ranged from 71$^{o}$ F to 80$^{o}$ F, which were within the BEHA comfort guidelines in all but one area, classroom 305. The BEHA recommends that indoor air temperatures be maintained in a range of 70$^{o}$ F to 78$^{o}$ F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Heat complaints were reported in classrooms 305 and 317, which were experiencing problems with heat control from the univents.

The relative humidity measured in the building ranged from 29 to 43 percent, which was below the BEHA recommended comfort range in the majority (13 of 19) of areas surveyed. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

**Microbial/Moisture Concerns**

At the time of the May 6, 2003 visit, Mr. Burchill reported that the third floor girl's restroom was experiencing leakage and showed signs of water damage to the ceiling and walls (Picture 5). In order for building materials to support mold growth, a source of water exposure is necessary. Identification and elimination of water moistening building materials is necessary to control mold growth. GW with increased moisture content over normal concentrations may indicate the possible presence of mold growth. Identification of the location of GW with increased moisture levels can also provide clues concerning the source mold growth. In an effort to ascertain moisture content of GW, measurements were taken in areas directly impacted by water damage as well as a number of non-effected areas in the restroom for comparison (Table 1). Water content of GW was measured with a Delmhorst, BD-2000 Model, Moisture Detector with a Delmhorst Standard Probe. The probe was inserted into the surface of GW at various heights.

The Delmhorst probe is equipped with three lights as visual aids to determine moisture level. Readings which activate the green light indicate a sufficiently dry moisture level (0 - 0.5%), those that activate the yellow light indicate borderline conditions (0.5 – 1.0%) and those that activate the red light indicate elevated moisture content (> 1%). Elevated moisture measurements were recorded in several areas. GW with elevated moisture readings was noticeably wet and soft to the touch. These results indicated that the building materials were moistened at the time of the assessment.

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials (e.g. GW) be dried with fans and heating within 24 hours of becoming wet (ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy materials is not recommended.

In subsequent correspondence with Mr. Burchill, it was reported that the source of moisture impacting GW was identified as a breach in exterior flashing. The breach was repaired and water damaged GW and ceiling tiles were replaced. BEHA staff confirmed these repairs during the August 8, 2003 visit.

Several classrooms contained a number of plants. Plant soil, standing water and drip pans can be potential sources of mold growth. Drip pans should be inspected periodically for mold growth and over-watering should be avoided. Plants should also be located away from univents to prevent aerosolization of dirt, pollen or mold.

Spaces between the sink countertop and backsplash were noted in room 11. Repeated leakage or improper drainage/overflow of water in sinks can lead to water penetration/damage of countertop wood, the cabinet interior, areas behind cabinets and carpeting. Like other porous materials, if these materials become wet repeatedly they can provide a medium for mold growth.

**Other Concerns**

Several other conditions that can potentially affect indoor air quality were also identified. Many rooms contained dry erase boards, markers and cleaners. Materials such as dry erase markers and dry erase board cleaners may contain volatile organic compounds (VOCs) (e.g. methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Spray cleaning products were found beneath sinks and on countertops in several classrooms. Cleaning products contain chemicals, which can be irritating to the eyes, nose and throat and should be stored properly and kept out of reach of students.

Finally, in an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs. Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and to off-gas VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g. spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix II (NIOSH, 1998).

## Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Contact the school's HVAC engineer and/or architect regarding the operation and function of the carbon dioxide monitor in the cafeteria. Maintain and calibrate it in accordance with the manufacturer's instructions.
2. Operate both supply and exhaust ventilation continuously during periods of school occupancy.
3. Contact the school's HVAC engineer to investigate and repair temperature controls in classrooms 305 and 317, as well as in other areas with heat complaints.
4. Confirm whether the ventilation systems were balanced as part of the recent renovations. If they have not been balanced, consult a ventilation engineer

concerning balancing of the systems. Ventilation industrial standards recommend that mechanical ventilation systems be balanced every five years (SMACNA, 1994).

5. Remove all blockages from univents to ensure adequate airflow.
6. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (e.g. throat and sinus irritations).
7. Ensure plants have drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary.
8. Store chemicals and cleaning products properly and out of the students' reach. Ensure products are properly labeled in the event of an emergency for identification purposes.
9. Consider discontinuing the use of tennis balls on chairs to prevent latex dust generation.
10. Consider adopting the US EPA document, "Tools for Schools", in order to provide self assessment and maintenance for a good indoor air quality environment in your building. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.

11. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

## References


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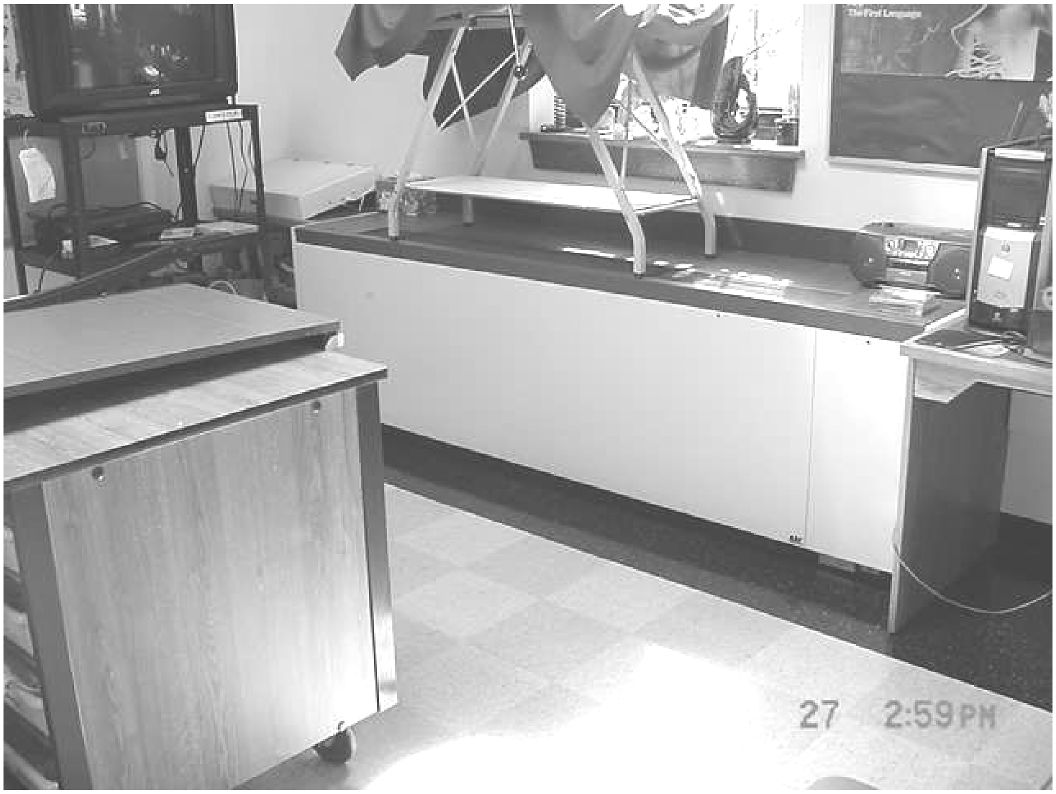
**Picture 1**




**Classroom Univent**

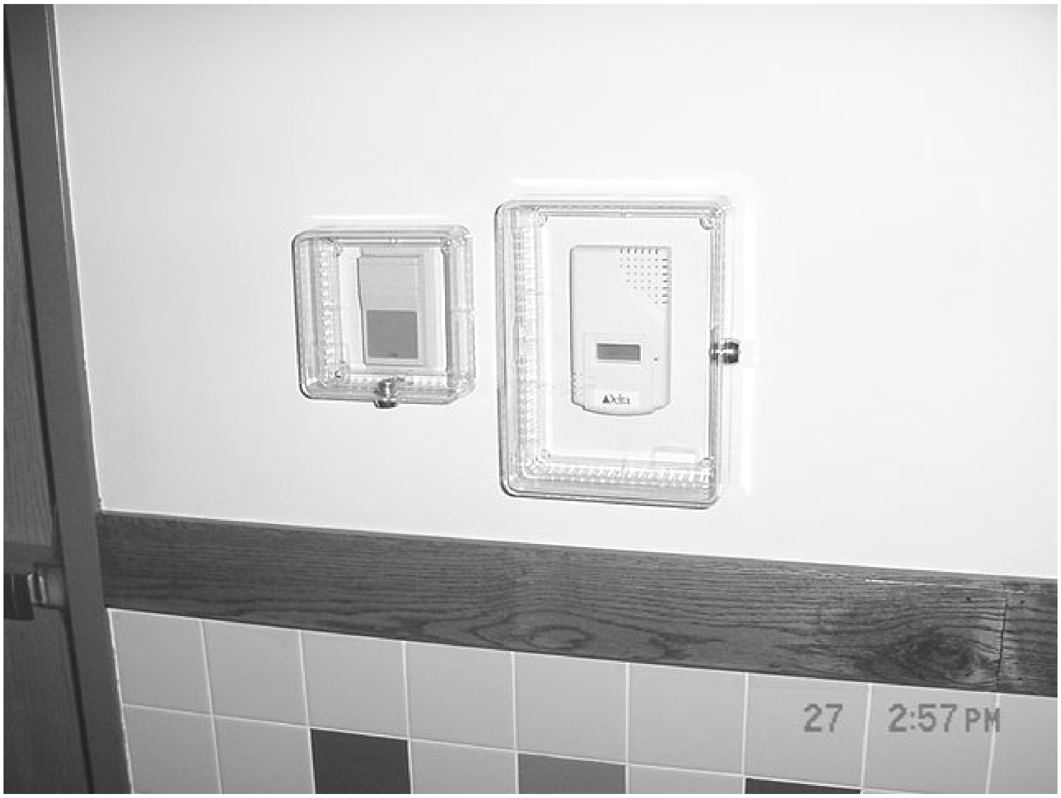
**Picture 2**


**Univent Fresh Air Intake**

**Picture 3**


**Classroom Exhaust Vent**

**Picture 4**




**Carbon Dioxide Monitor With Digital Readout in Cafeteria (on right)**

**Picture 5**

**Water Damaged GW in Third Floor Girls Restroom**

**TABLE 1**

## Indoor Air Test Results –Lincoln Elementary School, Winchester, MA May 6, 2003

| Location | Carbon Dioxide (*ppm) | Temp. (°F) | Relative Humidity (%) | Occupants in Room | Windows Openable | Ventilation | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Supply | Exhaust | |
| Outside (Background) | 460 | 60 | 45 | | | | | |
| Room 305 | 1080 | 80 | 35 | 26 | Y | Y | Y | Window/door open |
| Room 317 | 716 | 78 | 33 | 21 | Y | Y | Y | Window/door open, deactivated due to heat issues |
| Room 202 | 535 | 74 | 34 | 0 | Y | Y | Y | Plants on UV (flowering) |
| Room 203 | 542 | 76 | 34 | 0 | Y | Y | Y | Window open, pencil sharpener on UV |
| Room 101 | 676 | 73 | 41 | 24 | Y | Y | Y | Window open |
| Library | 470 | 71 | 43 | 2 | Y | Y | Y | |
| Room 103 | 503 | 74 | 39 | 0 | Y | Y | Y | Blocked by UV |
| Cafeteria | 1744 | 76 | 43 | 130+ | Y | Y | Y | $CO_2$ monitor on wall |
| Art Room | 518 | 72 | 40 | 0 | Y | Y | Y | Wasps nest over UV, kiln local exhaust system |

*** ppm = parts per million parts of air**
**UV = univent**
**DE = dry erase**

**Comfort Guidelines**

| | |
|---|---|
| Carbon Dioxide - | < 600 ppm = preferred |
| | 600 - 800 ppm = acceptable |
| | > 800 ppm = indicative of ventilation problems |
| Temperature - | 70 - 78 °F |
| Relative Humidity - | 40 - 60% |

TABLE 1

**Indoor Air Test Results –Lincoln Elementary School, Winchester, MA May 6, 2003**

| Location | Carbon Dioxide (*ppm) | Temp. (°F) | Relative Humidity (%) | Occupants in Room | Windows Openable | Ventilation Supply | Ventilation Exhaust | Remarks |
|---|---|---|---|---|---|---|---|---|
| Copy Room | | | | 0 | Y | Y | Y | Vent off, photo copier odors |
| Nurses Office | 577 | 74 | 41 | 1 | Y | Y | Y | |
| Principal's Office | 673 | 74 | 40 | 1 | Y | Y | Y | |
| Room 4 | 793 | 74 | 31 | 18 | Y | Y | Y | Cleaning agents on sink counter, DE |
| Teacher's Lounge Room 6 | 705 | 75 | 31 | 2 | Y | Y | Y | |
| Special Education Room 11 | 504 | 75 | 29 | 1 | Y | Y | Y | DE, cleaners on sink counter, missing caulking around sink |
| Room 10 | 542 | 75 | 29 | 0 | Y | Y | Y | |
| Music Room | 660 | 71 | 34 | 26 | Y | Y | Y | DE, plants on window sill |
| 3rd Floor Girl's Rest Room | | | | | Y | Y | Y | Water damaged GW saturated – 6.2 reading, moisture range 0.1-6.2, paint bubbling, noticeable mold odors |

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**UV = univent**
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| Temperature - | 70 - 78 °F |
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TABLE 1

## Indoor Air Test Results –Lincoln Elementary School, Winchester, MA May 6, 2003

| Location | Carbon Dioxide (*ppm) | Temp. (°F) | Relative Humidity (%) | Occupants in Room | Windows Openable | Ventilation | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Supply | Exhaust | |
| Room 311 | 982 | 76 | 32 | 22 | Y | | | DE, table near UV, cardboard trays on UV |
| Room 309 | 657 | 74 | 32 | 0 | N | Y | Y | |
| Room 310 | | | | | Y | Y | Y | Tennis balls on chair legs, windows open, personal fans |
| Room 316 | 499 | 74 | 32 | 2 | Y | Y | Y | Personal fans, cleaners under sink, plant growing light, cardboard trays, DE, wet cloth under plants, partially blocked exhaust vent |

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**UV = univent**
**DE = dry erase**

**Comfort Guidelines**

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|---|---|
| Carbon Dioxide - | < 600 ppm = preferred<br>600 - 800 ppm = acceptable<br>> 800 ppm = indicative of ventilation problems |
| Temperature - | 70 - 78 °F |
| Relative Humidity - | 40 - 60% |